Early Journal Content on JSTOR, Free to Anyone in the World

This article is one of nearly 500,000 scholarly works digitized and made freely available to everyone in the world by JSTOR.

Known as the Early Journal Content, this set of works include research articles, news, letters, and other writings published in more than 200 of the oldest leading academic journals. The works date from the mid-seventeenth to the early twentieth centuries.

We encourage people to read and share the Early Journal Content openly and to tell others that this resource exists. People may post this content online or redistribute in any way for non-commercial purposes.

Read more about Early Journal Content at http://about.jstor.org/participate-jstor/individuals/early-journal-content.

JSTOR is a digital library of academic journals, books, and primary source objects. JSTOR helps people discover, use, and build upon a wide range of content through a powerful research and teaching platform, and preserves this content for future generations. JSTOR is part of ITHAKA, a not-for-profit organization that also includes Ithaka S+R and Portico. For more information about JSTOR, please contact support@jstor.org.

DISEASE RESISTANCE IN CABBAGE

By L. R. Jones

College of Agriculture, University of Wisconsin

Communicated by R. A. Harper, December 31, 1917

The cabbage, while ordinarily one of the most vigorous of cultivated plants, is highly susceptible to certain parasitic diseases. The most destructive of these, known as 'yellows,' is due to a soil inhabiting fungus (*Fusarium conglutinans*) which invades the root system. Once introduced this parasite may persist indefinitely in the soil rendering it 'cabbage sick' so that this crop can no longer be grown upon it. One who knows the nature of this parasite and its manner of host invasion would have little hope of its practical control through any of the usual methods of spraying or seed or soil treatment. Extensive experimental trials have justified this conclusion.[1] On the other hand, when we were called upon in 1910 to investigate this disease and its control in Wisconsin, it was these very factors which encouraged the hope that it might be possible to secure disease resistant varieties or strains. The principle involved in such an undertaking is, of course, that of 'the survival of the fittest.' The things essential to any satisfactory progress are that there be among the host plants well marked variations in individual susceptibility or 'resistance' to the parasitic attacks and that this character, whatever its cause, be fixed and transmissible from generation to generation. Another very important matter, from the practical standpoint, is that such resistant characters be combined with those which give the plants economic value. Examination of the worst diseased fields led to the discovery of certain individual plants which developed apparently normally although all neighboring plants were dying or dead from the effects of the parasite. Moreover, among these survivors were to be found representatives of the best commercial types. The first and last conditions were therefore met. Would these characters persist in seed obtained from such plants?

Somewhat over 50 such resistant individuals were selected in the autumn of 1910, seed was grown from them in 1911, and in 1912 this seed planted, each 'head strain' separately, on the 'sickest' available soil. Omitting all details the general results may be summarized by the statement that in every case the selected head strains transmitted in considerable degree their resistant qualities, and certain of them did so in high degree. Thus of the control (non-selected) varieties the majority were killed by the parasite and most of the balance were so diseased that they failed to form heads, whereas the *poorest* of the selected head strains proved decidedly superior to the *best* of these controls, and of the best selected head strain 98% of the plants lived through the season and 93% of them formed heads. The figures which may best be cited are, however, those comparing the head strain which in the behavior of its progeny has since proved to be the best with the unselected control strains.

Selected head strain	96% lived	80% headed
Non-selected controls	36% lived	16% headed

From the best of these heads, selected as the second generation survivors on sick soil in 1912, seed was grown in 1913 and like trials on the same infected soil made again in 1914. In order the better to show the significance of these results the following summary includes the averages of *all* of the head strains selected from the best strain in 1912 together with the results from the *best* head strain. Data are also here included as to the per cent of diseased plants in each strain at the end of the season, the average weight of the heads, and the computed yields in tons per acre.

SECOND GENERAL TRIALS, 1914	LIVED	HEADED	DISEASED	WEIGHT PER HEAD	YIELD PER ACRE
	per cent	*per cent*	*per cent*	*pounds*	*tons*
Average all selected strains	99.5	94.0	5.0	4.0	12.2
Best selected head strain	100.0	98.0	1.5	5.5	18.8
Average non-selected controls	46.0	24.5	81.0	2.7	2.1

A comparison of the 1914 results with each other and with those of 1912 shows clearly certain encouraging things. First, the disease resistant character, whatever may constitute it, is fixed and inheritable; second, there is a distinct improvement in the second generation as compared with the first; third, there is enough variation as between the selected head strains of the second generation to furnish a basis for further possible improvement by continued selection. Perhaps this last idea requires restatement in such a way as to lay the emphasis upon another fact. Since there is a considerable variation within the progeny of even the selected head strains it is necessary to continue the method of growing the seed strains on 'sick' soil for trial and selection in order to maintain the highest standards, and were this to be discontinued there would probably be a tendency toward gradual reversion. Such selections and trials have since been continued in an intensive way by our department with further encouraging results while the more extensive work of seed growing and its distribution (under the name Wisconsin Hollander) has passed to the hands of a committee of practical cabbage growers organized for this purpose.

In this way our own departmental activities, including the investigations of certain graduate students, have been freed for direction to some of the more fundamental questions involved. Among these the following may be defined.

1. Wherein is the difference between the susceptible and the resistant plant? In other words, what constitutes disease resistance?

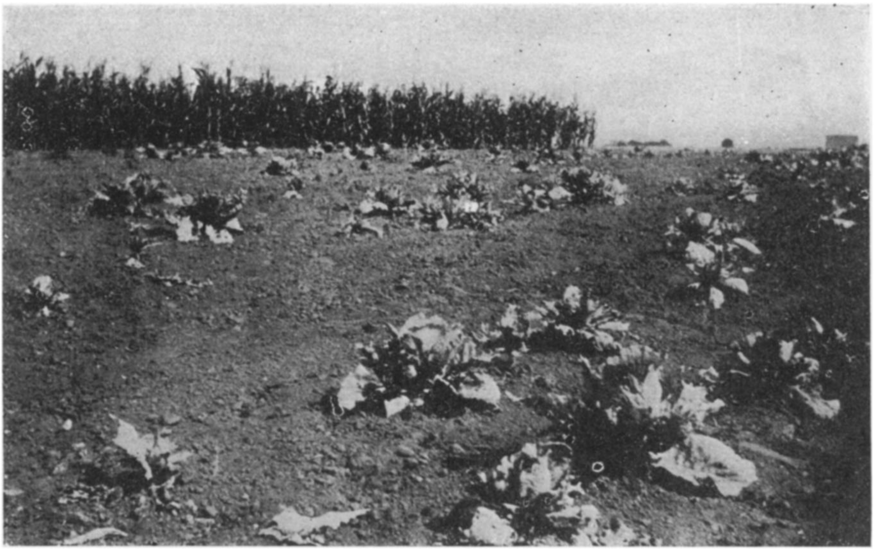

FIG. 1. A FUSARIUM-SICK CABBAGE FIELD

Note that while most of the plants are diseased or dead certain appear normal. Selections of such were made from this field in 1910.

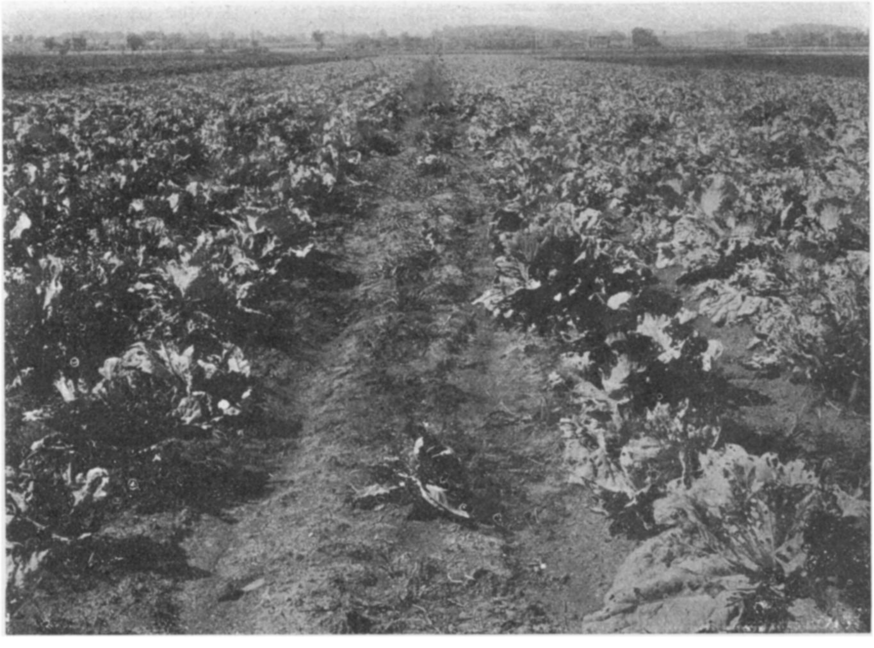

FIG. 2. A TRIAL OF RESISTANT STRAINS ON 'SICK' SOIL IN 1916

The central row, nearly all dead, is a commercial non-resistant strain planted as a control. The remainder of the field is planted with selected resistant strains, the first row at the left being recently selected kraut varieties, Brunswick and All Seasons, the rest being Wisconsin Hollander.

2. How does this factor of disease resistance behave in inheritance? Is it surely transmissible and does it 'Mendelize?'

3. Is the quality of resistance or susceptibility influenced by environmental factors, if so, how? Related to this is the question as to whether such resistance will persist when the strain selected in one locality, e.g., Wisconsin, is grown in a remote locality, e.g., New Jersey.

4. Is the principle general? In other words, is there similar variation in individual susceptibility and resistance to this parasite among other varieties of cabbage than the one considered above? How general is the occurrence of such differences with other host plants and other plant parasites?

While wholly satisfying answers are not yet formulated for any of these questions, such evidence as has been secured may be summarized as follows.

As bearing on the first question, W. H. Tisdale, working in our laboratory, has sought to learn what difference there is in the relations of the parasite to the resistant and the susceptible plants. Since the cabbage is a clumsy plant of slow development he used for his primary investigations the flax which is invaded by a closely similar parasitic Fusarium and which has well differentiated resistant and susceptible strains. Secondary comparative studies with the cabbage, while not yet complete, indicate a general likeness in behavior. He has learned that the difference in resistance is not due to any superficial obstacle since the parasite, which may enter through the root hairs, penetrates these freely in the resistant as well as the susceptible plants. The difference is in the relations of the interior cells of the host and the parasite. In the suceptible plants the parasite penetrates directly to the vessels and then ramifies through them to the destruction of the host. In the resistant individuals, on the other hand, the invasion advances more slowly and before it reaches the vessels is checked and permanently walled off by the development of a corky layer. This reaction may be interpreted in various ways but the one we favor is that the resistant tissues have the ability to restrain the development of the parasite to a greater degree than do the susceptible and so give time for the protective cork formation.

With reference to the second question, Tisdale[2] has also sought to follow the behavior of resistance as an inherited character again using the flax. Biffin, in England, working with wheat, concluded that resistance to the rust parasite (Puccinia) was inherited as a simple Mendelian character, being recessive. With flax the problem proves not so simple. Crossing highly susceptible with resistant strains and testing the progeny shows that resistance is clearly a transmissible character, but the hybrids are in general more or less intermediate in this respect with a tendency for resistance to be dominant. Much variation is found in lines originating from different parents. The indications are that resistance is not a single character but a complex, dependent upon a number of heritable factors.

As to the third question, environmental factors do have a marked influence in determining whether the Fusarium parasite will invade the cabbage. J. C.

Gilman working at Wisconsin and later at the Missouri Botanical Garden found that there is a 'critical soil temperature,' about 17°C., for such invasion. Below this the plants are not parasitized, even in the sickest soils while for some 10° above this the attack becomes progressively more virulent. Correlated with this is the experience that at lower soil temperatures, e.g., in cool summers, there is little disease even with susceptible strains and in hot summers there is a certain amount of infection even with our most resistant strains. It is theoretically possible, therefore, that a strain which was resistant in a relatively cool climate might prove susceptible when transferred to a warmer region. As a matter of field trial, however, these resistant Wisconsin cabbage strains have proved similarly resistant under trials extending from New Jersey to Iowa.

Regarding the fourth question we may speak with considerable confidence also. Our earlier work was confined, as previously suggested, to one cabbage variety, the Hollander. Selections which have since been made from other varieties, both in connection with our own investigations and by others in Ohio, Iowa and Maryland, have given encouraging results. We may be reasonably confident, therefore, that a Fusarium-resistant strain of cabbage may be secured from any vigorous established variety.

If we do not ask for too much in the way of practical application we may safely go farther in the generalization as to the occurrence of disease resistance in plants. Plants are always varying of course, and this includes variations in those factors which make them more or less susceptible or resistant to the attacks of any parasite. Unquestionably constantly increasing recognition of this principle will be given by plant breeders and plant pathologists in seeking to control plant diseases. On the other hand, experience indicates that with parasites of certain kinds including the Fusariums, it is relatively easier in practice to secure disease-resistant strains of host plants than it is with many other parasites, for example the common wheat rust.

---

[1] For a more detailed consideration of these matters reference may be made to *Wis. Agric. Exp. Sta. Res. Bul.*, 38, The Control of Cabbage Yellows through Disease Resistance, by L. R. Jones and J. C. Gilman, December, 1915.

[2] Tisdale did his work on inheritance as a graduate student under the direction of Dr. L. J. Cole in the department of experimental breeding, at the University of Wisconsin. His results along these two lines have been formulated for publication in the *Journal of Agricultural Research.*